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(54) **STEREO CAMERA-BASED AUTONOMOUS DRIVING METHOD AND APPARATUS**

VERFAHREN UND VORRICHTUNG FÜR AUF EINER STEREOKAMERA BASIERENDES, AUTONOMES FAHREN

PROCÉDÉ ET APPAREIL DE CONDUITE AUTONOME À BASE DE CAMÉRA STÉRÉO

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(56) References cited:
WO-A1-2016/086379
US-A1- 2012 113 232
US-A1- 2012 143 430
US-A1- 2016 205 384
US-B1- 9 221 396

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Description

BACKGROUND

1. Field

[0001] The following description relates to a stereo camera-based autonomous driving method in accordance with the preamble of claim 1 and an autonomous driving apparatus in accordance with the preamble of claim 7 Such a method and apparatus are described in US 2021/143430 A1.

2. Description of Related Art

[0002] Autonomous driving may include driving performed by a vehicle without manipulation of the vehicle by a user, e.g., the driver of the vehicle, and/or providing alternate conveniences to the user while driving. Recognition of the three-dimensional (3D) environment surrounding a vehicle may be desired for the autonomous driving. For example, a stereo camera, an infrared light camera, a proximity sensor, an ultrasonic sensor, radar, and/or lidar may be used for the recognition of the surrounding 3D environment of the vehicle.

[0003] Reference is made furthermore to prior-art documents US 2012/0113232 A1; US 2016/0205384 A1; US 9,221,396 B1 and US 2012/0143430 A1.

SUMMARY

[0004] According to the invention a method in accordance with claim 1 and an apparatus in accordance with claim 7 is provided.

[0005] Preferred embodiments of the present invention are subject of the appended dependent claims. The following examples do not necessarily form part of the invention as defined in the claims but represent background art that is useful for understanding the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006]

FIG. 1 illustrates an example of an autonomous driving apparatus.
FIG. 2 illustrates an example of a camera array.
FIG. 3 illustrates an example of movable cameras, not covered by the invention as defined by the claims.
FIG. 4 illustrates examples of blind spot distances and depth measurement areas based on different widths of a stereo camera.
FIG. 5 illustrates an example for depth errors of disparity measurements performed in units of pixel.
FIGS. 6A and 6B illustrate examples of stopping distances in different driving conditions.
FIG. 7 illustrates an example of a controlling of a width of a stereo camera based on a stopping distance.
FIG. 8 illustrates an example of a controlling of a width of a stereo camera based on a threshold blind spot distance.
FIG. 9 illustrates an example of an autonomous driving apparatus.
FIG. 10 illustrates an example of an autonomous driving method.

[0007] Throughout the drawings and the detailed description, unless otherwise described or provided, the same drawing reference numerals will be understood to refer to the same or like elements, features, and structures. The drawings may not be to scale, and the relative size, proportions, and depiction of elements in the drawings may be exaggerated for clarity, illustration, and convenience.

DETAILED DESCRIPTION

[0008] The following detailed description is provided to assist the reader in gaining a comprehensive understanding of the methods, apparatuses, and/or systems described herein.

[0009] FIG. 1 illustrates an example of an autonomous driving apparatus. Referring to FIG. 1, an autonomous driving apparatus 100 includes a capturer 110 and a controller 120, as only examples. The capturer 110 performs capturing in a first direction, for example, using two or more cameras that output captured images of the first direction. The first direction includes one of a front direction, a rear direction, and any side direction, for example. In the first direction, a depth measurement area is formed where the fields of view of two example cameras overlap each other. The depth

measurement area may represent a field of view of a stereo camera corresponding to the two examples cameras. The controller 120 measures a depth of an object located in the depth measurement area of the first direction based on output images of the two cameras. For example, the controller 120 performs stereo matching on the output images of the two cameras to measure the depth of the object. Also, the controller 120 may recognize or determine a three-dimensional (3D) location of the object that includes information of the depth. For example, respective disparities can be measured for determined corresponding/matched objects or points respectively in the output images of the two cameras, to discern the depth of the object. In an example, e.g., where disparity is measured in pixel units, the disparity may represent the pixel distance (e.g., number of pixels) between the image position of a point or object in a first image plane and the image position of the matched/corresponding point or object in the second image plane, for example. In an example, a disparity map or depth map may be generated by the controller 120 based on the measured disparities, such as for determining the depth of determined objects or points. In addition, the matching or correspondence between such points or objects between the two images can be determined according to different approaches, with a simple approach including a block matching algorithm applied between the two images. Though examples have been discussed for measuring the depth of an object using multiple images, e.g., two captured images, differing approaches and methodologies are available for determining the position and/or depth of objects from multiple images, and thus embodiments are not limited to only to such examples described herein.

[0010] The capturer 110 may be provided through a structure in which a distance between the two cameras is adjustable and/or different cameras are selectable for representing the stereo camera, so the two cameras are capable of being used for stereo vision. The controller 120 appropriately adjusts the distance between the two cameras and/or selects the cameras so as to have a corresponding distance therebetween, based on a determined or estimated driving situation of a vehicle. The distance between the two cameras is a distance by which the two cameras representing the stereo camera are spaced apart from each other in order to form a binocular disparity and also referred to herein as, for example, a width of the stereo camera.

[0011] As further discussed below, the width of the stereo camera affects a width, depth, or extent of a blind spot area outside of the depth measurement area and a maximum measurable depth of the stereo camera within the depth measurement area. Using FIG. 1 as an example, the maximum measurable depth value represents a depth that can be maximally measured in the illustrated vertical direction matching the driving direction of the vehicle, for example, while the corresponding blind spot area represents an area in which a depth measurement in a horizontal direction, i.e., perpendicular to the driving direction, is unavailable or unobservable at least from the stereo camera.

[0012] While the maximum measurable depth increases as the width of the stereo camera is increased, the blind spot area also increases with the increase in the width of the stereo camera. Conversely, a decrease in the width of the stereo camera results in a decrease in the maximum measurable depth and a decrease in the blind spot area. As such, the maximum measurable depth and the blind spot area are in a trade-off relationship and thus, the width of the stereo camera may be adjusted based on this trade-off relationship and the driving situation. For example, when driving at high speed, recognition of a far object at a long distance from the vehicle may be desirable to obtain a safe distance with other traffic. Thus, the controller 120 may increase the width of the stereo camera to reach a predetermined level. Here, though this increasing of the width of the stereo camera may also increase the blind spot area, it may be determined that there is a greater value or priority in the greater depth measuring capability. Alternatively, when driving at low speed, it may be more desirable to give greater value or priority to a wider visual field than the greater depth measuring capability in preparation for changing lanes, a change in direction, or a possible obtrusion of another vehicle, so the controller 120 may decrease the width of the stereo camera to reach a different predetermined level.

[0013] The controller 120 may estimate the driving situation of a vehicle and, based on that estimation, determine a parameter associated with the width of the stereo camera. The controller 120 may estimate the driving situation based on information associated with the driving situation. The controller 120 may also receive an estimation result of the driving situation from another device. For example, the controller 120 receives the information associated with the driving situation from at least one of one or more sensors included in the vehicle and/or one or more sensors or devices external to the vehicle, and estimates the driving situation based on the received information. Also, the controller 120 may receive the estimated driving situation as estimated by at least one of the sensors included in the vehicle or the external sensors or devices. The controller 120 may further receive a mixture of such estimated driving situation results from one or more of the sensors included in the vehicle and the external sensors and/or devices and make a final estimation of the current driving situation based on the received estimated driving situations and the collected/received information associated with the driving situation.

[0014] The different driving situations may include at least one of driving at high speed, driving at low speed, driving on a highway, driving in a city, driving straight ahead, changing lanes, changing direction, an obtruding vehicle or obstacle, a weather condition, or a road condition, as only non-limiting examples. Whether the vehicle is driving at a high speed and or at a low speed may be determined based on a predetermined reference value. For example, when a speed of the vehicle is greater than or equal to the reference value, the driving situation may be determined to be that the vehicle is driving at high speed. Conversely, when the speed of the vehicle is less than the reference value, the driving situation

may be determined to be that the vehicle is driving at low speed. There may also be multiple such reference values so as to have multiple driving speed situations from the vehicle driving very fast to the vehicle driving very slow, for example. Whether the vehicle is driving on a highway and/or whether the vehicle is the driving in a city may be determined based on a determined location of the vehicle, such as determined through a global positioning system (GPS) of the vehicle or alternate device and/or object/location recognition from the camera(s) captured images. There may also be other location based driving situations. Whether the vehicle is driving straight ahead, changing lanes, or changing direction, as only examples, may be determined based on a determined or measured moving direction of the vehicle and/or a user action or manipulation with respect to the vehicle. For example, the changing of lanes driving situation or the changing of direction driving situation may be determined in response to a change in the moving direction of the vehicle, a steering manipulation of a user, or a direction indicating manipulation of the user. The controller 120 may also acquire weather information of a current location of the vehicle from, for example, a connectable or connected to weather center database or server, e.g., based on determined GPS information. Also, the controller 120 may predict the road condition based on a result obtained by analyzing an image capturing a current driving road and/or the weather information. The driving condition may also be indicated orally by the user speaking into a microphone of the controller 120.

[0015] As only examples, the sensor(s) and/or the external device(s) may sense and record at least one of the speed of the vehicle, the moving direction of the vehicle, the location of the vehicle, and the user manipulation using one or more general schemes. The user manipulation may include, for example, the steering manipulation, the direction indicating manipulation, an accelerating manipulation, a decelerating manipulation, and a parking manipulation of the vehicle. The user manipulation may be input through a steering device, a direction indicating device such as a turn signal lever or indicator, an accelerating pedal, a braking pedal, and a parking brake of the vehicle, as only examples. The controller 120 receives information sensed by at least one of the corresponding sensors and/or the external devices and may estimate the driving situation based on the sensed information. Also, the sensors and the external devices may estimate the driving situation based on the sensed information and inform the controller 120 of their respectively estimated driving situation. In addition, in one or more embodiments, based on information from such differing sensors or determined conditions and based on previous training data, the controller 120 may also estimate the driving situation by providing such information to a driving situation model or other deep learning, machine learning, or hierarchical analytics that may be trained or designed based on such training data and, depending on embodiment, updated through confirming or negating interaction with the user regarding the results of the estimated driving situations and through other updating mechanisms, such as by connectable or connected manufacture databases or servers.

[0016] The controller 120 determines or sets the parameter associated with the width of the stereo camera based on the estimated driving situation. For example, the parameter may have a value corresponding to or indicating a desired width of the stereo camera. As further discussed below, the controller 120 may determine a minimum value and a maximum value of such a parameter based on the estimated driving situation and determine or set the parameter to be a value between the maximum value and the minimum value, so the stereo camera has a width determined appropriate for the estimated driving situation. The controller 120 controls the capturer 110 such that the two cameras included in the capturer 110 have a distance therebetween that corresponds to the parameter. Thus, the controller 120 controls the two cameras to capture respective images having the controlled arrangement therebetween according to the parameter. Accordingly, the capturer 110 provides captured image information suitable for the estimated driving situation using the stereo camera, represented by the two cameras, having the width corresponding to the parameter. With such an arrangement, the autonomous driving apparatus 100 acquires and generates autonomous driving or controlling information that is suitable for the driving situation using the cameras of the capturer 110 at a relatively small cost, compared to typical systems that require the use of higher cost lidar or radar systems, for example, to obtain surrounding information.

[0017] The controller 120 may control another parameter of the stereo camera based on the driving situation as well as the parameter associated with the width of the stereo camera. For example, the other parameter may be a parameter associated with a visual field direction of the stereo camera. In this example, the controller 120 may predict a driving direction of the vehicle using information from the steering device or the direction indicating device and adjust a parameter for controlling a rotational angle and/or a horizontal visual field width of the stereo camera based on the predicted driving direction of the vehicle. As further discussed below, in an example, the controller 120 may control the horizontal visual field width using a camera array of the capturer 110. Also, in an example, the controller 120 may control the rotational angle using movable and/or rotatable cameras of the capturer 110.

[0018] Using the captured images from the stereo cameras with the respectively set stereo camera widths, the controller 120 may control the determination of the depth of objects observed in the captured images. For example, the controller 120 may generate a depth map of the 3D surroundings of the vehicle. From the determined depths, the controller 120 may determine whether observed objects are potential obstructions or are nearing the vehicle, such as another vehicle nearing the vehicle from another lane, which may be determined by the controller 120 by comparing captured images of the stereo camera(s) over time. The controller may further perform respective object classification and/or recognition, as well as global and/or local localization and mapping of the vehicle and the detected object(s). Based on the such object detection, classification, and/or recognition and the global or local localization and mapping, the controller 120

may perform safe path planning for the vehicle, which can be displayed to the driver of the vehicle, such as through display of the vehicle, or used in autonomously driving of the vehicle without user control, depending on embodiment.

[0019] FIG. 2 illustrates an example of a camera array. Referring to FIG. 2, a capturer 210 includes a camera array 215, and may correspond to the capturer 110 of FIG. 1, though embodiments are not limited thereto. The camera array 215 includes a plurality of cameras. The plurality of cameras may be arranged at preset intervals, for example, and attached to a frame. When the plurality of cameras are attached to the frame, the example preset intervals separating the plurality of cameras are maintained as an initially set value. As an alternative, the plurality of cameras may be arranged according one or more different preset intervals. A controller 220 determines or sets a parameter associated with a width of a stereo camera based on an estimated driving situation, and selects two cameras from the camera array 215 having a distance therebetween corresponding to the determined or set parameter. For example, when the stereo camera width corresponding to the parameter is a width d, the controller 220 may select any of cameras 1 and 4, cameras 2 and 5, cameras 3 and 6, cameras 4 and 7, or cameras 5 and 8 of FIG. 2, respectively separated by widths d.

[0020] When there are numerous cameras at preset intervals, the controller 220 may select two cameras from among the cameras for the stereo camera based on a predetermined reference. In one example, such as when the driving situation is estimated to be that the vehicle is driving directly forward, the controller 220 may be select cameras based on their respective distances from a centerline of the camera array 215. For example, when the stereo camera width corresponding to the determined or set parameter is d, the controller 220 may select cameras 3 and 6 which are separated by the stereo camera width d and are equal distant from the centerline of the camera array 215. In another example, the controller 220 may select cameras based on their relative closeness to a side to which a determined priority has been assigned, e.g., select the camera that is closest to the prioritized side as one of the two cameras of the stereo camera, based on the estimated driving situation. For example, when another vehicle obtrudes or an obstacle is detected from the illustrated right side or there is a determined greater potential for such obtrusion or obstacle based on the estimated driving situation, the controller 220 may assign the priority to the illustrated right direction. In this example, for the same stereo camera width d, the controller 220 may select cameras 5 and 8 closer to the right side as the two cameras representing the stereo camera. Also, the controller 220 may predict the driving direction of the vehicle, and may select cameras based on their relative closeness to the predicted driving direction, e.g., select the camera that is closest to the predicted driving direction as one of the two cameras of the stereo camera, and thus may adjust the horizontal visual field width of the stereo camera. The controller 220 may operate the remaining cameras other than the selected cameras in a standby or power off mode, or they may be used for duplicative or other purposes.

[0021] In this regard, in one or more embodiments, the controller 220 may selectively operate other cameras or other stereo cameras, either of the capturer 210 or another capturer, in respective standby or power off modes when the controller 220 determines that image capturing in the corresponding respective field of view directions are not necessary for driving according to the predicted driving direction, such as to save power and resources of the autonomous driving apparatus. For example, if the predicted driving direction is determined to represent a left turn in a right side driving intersection, the controller 220 may control cameras facing toward the left, forward, and right sides of the vehicle to be capturing images for object detection and turn off cameras facing rearward, and potentially one or more of the left and right side cameras may be selectively controlled, such as discussed below with respect to FIG. 3, to move to provide more of forward-left and forward-right fields of view compared to fields of view that include rearward-left or rearward-right directions. If the predicted driving direction is determined to represent a right turn in such an intersection, then a different selection and arrangement of cameras may be chosen, such as to provide left, forward-left, forward, forward-right, right, and rearward-right fields of view. If the predicted driving direction is determined to represent a changing of lanes to the right, for example, then forward, forward-right, right, and rearward-right fields of view may be provided and remaining cameras maintained or turned off. Alternatively, if the predicted driving direction was determined to represent the changing of lanes to the left, then forward, forward-left, left, and rearward-left fields of view may be provided and remaining cameras maintained or turned off. As another example, if an obtruding vehicle is detected, such as a vehicle obtruding laterally from a right lane into a current lane directly into the front field of view, then forward-left, forward, forward-right, right, and rearward-right fields of view may be chosen and corresponding cameras controlled to capture images, while cameras arranged for other fields of view may be selectively maintained or turned off. Any of such cameras may be stereo cameras so the controller(s) 220 may determine the corresponding parameter for the respective stereo camera widths based on the estimated driving situation. In addition, though several examples have been given of select cameras of the autonomous driving vehicle being controlled or selectively controlled in power off modes, for different driving situations, embodiments should not be limited thereto as additional and alternative examples are also available.

[0022] FIG. 3 illustrates an example of movable cameras, not covered by the invention as defined by the claims. Referring to FIG. 3, a capturer 310 includes at least two cameras 315, and may correspond to the capturer 110 of FIG. 1, though embodiments are not limited thereto. As only examples, the two cameras 315 may move along a predetermined route 313, or move along respective predetermined routes. The predetermined route 313 may be implemented as a rail, a chain, or a belt, noting that embodiments are not limited thereto. The capturer 310 may include, for example, a step motor configured to move the two cameras 315 along the predetermined route 313, noting that alternative mechanisms

for respectively moving one or more of the cameras are also available. In an example, the two cameras 315 are controlled to move on the predetermined route 313 independently of each other to adjust a distance therebetween, or alternatively only one of the cameras may be controlled to move to increase or decrease the stereo camera width represented by the two cameras. For example, the controller 320 determines a parameter associated with the stereo camera width for an estimated driving situation and causes the two cameras 315 to move, if necessary, such that the two cameras 315 have a distance therebetween corresponding to the parameter.

[0023] The controller 320 controls the distance between the two cameras 315 based on the stereo camera width and arranges the two cameras 315 in respective appropriate locations. In one example, the controller 320 adjusts the location(s) of the two cameras 315 such that a centerline between the two cameras 315 corresponds to a centerline of the capturer 310 in a state in which the two cameras 315 provide the stereo camera width corresponding to the parameter. In another example, the controller 320 adjusts the location(s) of the two cameras 315 such that the centerline of the two cameras 315, arranged according to the stereo camera width, is positioned more in a direction to which a priority has been assigned. For example, when another vehicle has been determined to advance or obtrude from the left side or an obstacle is detected as nearing the left side, or when a left direction is predicted as a driving direction of the vehicle, the controller 320 may assign a priority to the left side. In this example, the controller 320 adjusts the locations of the two cameras 315 such that a centerline of the two cameras 315, arranged according to the stereo camera width, is positioned leftward relative to the centerline of the capturer 310. Alternatively, the controller 320 may rotate, such as through one or more corresponding servos represented by the capturer 310, one or both of the two cameras 315 leftward to prioritize the left side. The controller 320 may alternatively respectively perform both the location and rotational angle control of one or both of the two cameras 315 based on the estimated driving situation.

[0024] FIG. 4 illustrates examples of blind spot distances and depth measurement areas based on different widths of a stereo camera for an object recognition device, such as any or any combination of the controllers of FIGS. 1-3 and 9. FIG. 4 illustrates a depth-measured area and blind spot distances in a case 410 in which a stereo camera width is D1 and a depth-measured area and blind spot distances in a case 420 in which a stereo camera width is D2, D2 being greater than D1. The depth-measured areas refer to respective measurement areas for which depths are measured or available for measurement. Thus, as illustrated in FIG. 4, a maximum measurable depth and the blind spot distances in the case 410 are less than a maximum measurable depth and the corresponding blind spot distances in the case 420. Thus, in the case 410, while the object recognition device may obtain a visual field that is wider than that of the case 420, an object at a relatively long distance may only be recognized in the case 420 because of the greater maximum measurable depth in the case 420.

[0025] As discussed in the foregoing explanation, the width of the stereo camera affects the blind spot areas. Because the blind spot areas are outside of the depth measurement area, depth measurement by the stereo camera may be impossible in the blind spot areas. As demonstrated in FIG. 4, with an increase in the width of the stereo camera from D1 to D2, the maximum measurable depth between case 410 and case 420 also increases. In addition, as the width of the stereo camera increases, the depth error of the respective maximum measurable depths decreases. Thus, when the driving situation is estimated to be that the vehicle is driving at high speed, a visual field securing a longer distance measurement may be desirable or prioritized, e.g., over a wider visual field, so the width of stereo camera may be increased to be greater than or equal to a predetermined level that is set for that driving situation.

[0026] To demonstrate the increase of the blind spot area that occurs with the increase in the width of the stereo camera, the blind spot area will be discussed with respect to FIG. 4 using the illustrated blind spot distances. Each illustrated blind spot distance indicates a respective distance between the corresponding depth-measured area and a reference line. In this example, the reference line is set to be a line that extends from a front side of a capturer, a camera lens, an image sensor, or a front side of the vehicle, as only example, across one or more adjacent lanes, such as in a direction perpendicular to an axis of at least one of the cameras of the stereo camera. With respect to FIG. 4, the blind spot distances of the respective most adjacent lanes in case 410 and case 420 will be referred to as the first blind spot distances, and the blind spot distances of the respective subsequently adjacent lanes will be referred to as the second blind spot distances. For brevity of description, the following explanation will be provided based on the first blind spot distance and the description of the first blind spot distance is also applicable to the second blind spot distance. The probability of recognizing a distance of an object located in an adjacent lane decreases as the blind spot distance increases, e.g., due to a narrowing of the field of view. Accordingly, in preparation for changing lanes, changing direction, or a sudden obtrusion of another vehicle or an obstacle, the width of the stereo camera may be decreased to be equal to or less than a predetermined level set for the driving situation of the vehicle driving at low speed, for example, where the recognition of the object in the adjacent lanes may be more desirable. Thus, in the examples of FIG. 4, in the case 410 the stereo camera width D1 may be more suitable for driving situation of the vehicle driving at low speed, such as driving on a general roadway, and in the case 420 the stereo camera width D2 may be more suitable for the driving situation of the vehicle driving at high speed, such as driving on a highway.

[0027] FIG. 5 illustrates an example for depth errors of disparity measurements performed in units of pixel. As illustrated in FIG. 5, a pixel-based disparity decreases as the depth between an object and a stereo camera increases. Here, it is

noted that as the pixel-based disparity decreases, the depth error increases. The depth error may be a value indicating an error range of a depth of an object predicted using the pixel-based disparity measured as a result of a stereo matching operation performed by a controller, such as any of the controllers of FIGS. 1-3 and 9. The stereo matching may be performed between the respective captured images of the two cameras of the stereo camera, e.g., to match the same object in the separate captured images. As only an example, the pixel-based disparity can be the measurement, e.g., by the controller, of the number of pixels separating the object in the captured images.

[0028] For example, it may be assumed that, for the stereo camera of FIG. 5, a focal length f is 3.3 millimeters (mm), a width D of the stereo camera is 25 mm, and a pixel size δ is 40 micrometers (μm). In this example, as illustrated in FIG. 5, the disparity for an object at a depth between 0.45 meters (m) and 0.5 m would be 4, the disparity for an object at a depth between 0.5 m and 0.8 m would be 3, the disparity for an object at a depth between 0.8 m and 1.4 m would be 2, the disparity for an object at a depth between 1.4 m and 4.1 m would be 1. Also, in this example, the depth error is $\pm$ 0.025 m when the disparity is 4, the depth error is $\pm$ 0.15 m when the disparity is 3, the depth error is $\pm$ 0.3 m when the disparity is 2, and the depth error is $\pm$ 1.35 m when the disparity is 1.

[0029] The depth of an object may be obtained according to the below Equation 1, for example.

Equation 1:

$$Z = \frac{fD}{d}$$

[0030] In Equation 1, Z denotes a depth, f denotes a focal length of the stereo camera, D denotes a width of the stereo camera, and d corresponds to the disparity. In addition, the below example Equation 2 may be obtained by performing partial differentiation on both sides of Equation 1.

Equation 2:

$$\partial Z = \frac{D}{d}\partial f + \frac{f}{D}\partial D - \frac{fD}{d^2}\partial d$$

[0031] In Equation 2, when it is assumed that f and D are fixed characteristics, Equation 2 may be represented as the below Equation 3, for example.

Equation 3:

$$\partial Z \approx \frac{fD}{d^2}\partial d = \frac{Z^2}{fD}\partial d$$

[0032] Thus, in Equation 3, the depth error ∂Z is shown to be proportional to a square of depth Z^2. Here, it is also noted that this proportionality between ∂Z and Z^2 may be different from the proportionality between any lateral error (ΔX) in the observed location of an object with the stereo camera and the depth Z, where ΔX may be proportional to Z. For example, with the example configuration of FIG. 5, where the focal length f is 3.3 millimeters (mm), the width D of the stereo camera is 25mm, and the pixel size δ is 40 micrometers (μm), ΔX may be 0.7 cm when Z is 0.5 m, ΔX may be 1.7 cm when Z is 1.4 m, and ΔX may be 5 cm when Z is 5 m.

[0033] As discussed in the foregoing explanation, with an increase in the width of the stereo camera, a field of view may narrow which may result in increased blind spot area, the maximum measurable depth increases, and a depth error of the maximum measurable depth decreases.

[0034] Conversely, with a decrease in the width of the stereo camera, the field of view may widen which may result in decreased blind spot area, the maximum measurable depth decreases, and the depth error of the maximum measurable

depth increases. Here, the reference to a maximum measurable depth refers to a measurable depth for the stereo camera without unsatisfactory error and/or not outside the capabilities of the cameras of the stereo cameras, such as based on the pixel resolution of the captured images of the cameras and/or maximum distance for which measurable disparity can exist or be detected. For example, FIG. 4 demonstrates different depth measured areas for cases 410 and 420, which also respectively illustrate different example maximum measurable depths, and FIG. 5 illustrates an example where at a depth of 4.1 m there may be at most a 1 pixel disparity between pixels in the respective captured images by the cameras of the stereo camera. From Equation 3, the below example Equation 4 may be derived for a depth error ΔZ for a maximum measurable depth.

Equation 4:

$$\Delta Z \approx \frac{Z^2}{fD}\delta$$

[0035] In Equation 4, Z denotes the maximum measurable depth of the stereo camera, f denotes the focal length of the stereo camera, D denotes the width of the stereo camera, δ denotes a size of a pixel, and ΔZ denotes the depth error of the measurable depth. Also, in Equation 4, it can be seen that ΔZ is proportional to Z^2 and δ, and inversely proportional to f and D. Thus, ΔZ decreases in accordance with a decrease in D, just as ΔZ increases in accordance with an increase in D. Here, Equation 4 may also be representative of the relationship between the depth error and other depths in addition to the example maximum measurable depth.

[0036] With automobile navigation, in one or more embodiments ΔZ of a measured depth may be of interest when determining a minimum safe separation between traveling vehicles, e.g., a safe distance, which an autonomous vehicle according to one or more embodiments may determine based on a determined driving speed and measured distance to the immediately forward vehicle, e.g., when both vehicles are driving in the forward direction. In such a driving situation, the stopping distance of the following vehicle, at different speeds, may be known or calculated, such as based on experimental results or modeling. As noted below, the stopping distance may include the distance, e.g., braking distance, it physically takes to stop the vehicle from the point when a mechanical stopping operation is initiated and the distance, e.g., reaction distance, traveled during the reaction time it takes the vehicle controller or a user to determine that such stopping is to be performed and initiate the mechanical stopping operation. Here, the vehicle controller may be any of the vehicle controllers of FIGS. 1-3 and 9, as only examples. Accordingly, it may be desirable that the real distance for the stereo camera be at least the stopping distance.

[0037] Thus, in consideration of ΔZ, Z - ΔZ may represent such a safe distance enabling a depth of a target object to be measured without an occurrence of an error to avoid an accident because of the real distance between the target object and the vehicle being closer to the vehicle than the measured Z by the full possible extent of the ΔZ error. It should also be considered that a depth of an object located farther than the safe distance may not be accurately measured, such as when Z represents the maximum measurable depth and the object is outside of the depth measurement area for a set width of the stereo camera. Conversely, when the stopping distance required to stop the vehicle is greater than the maximum measurable distance - the corresponding ΔZ, i.e., the safe distance, an accident may occur. Thus, the width D may be selectively adjusted such that the safe distance is greater than or equal to the stopping distance.

[0038] FIGS. 6A and 6B illustrate examples of stopping distances in different driving conditions. Referring to FIGS. 6A and 6B, the stopping distances include the respective braking distances and reaction distances. The reaction distances represent the distances that the vehicle moves until a decelerating manipulation is input, such as by the controller of the autonomous vehicle or by the user, after an obstacle is detected, for example, such as by the user or the controller of the autonomous vehicle. The braking distance indicates a distance that the vehicle moves from the time at which the decelerating manipulation is input until the vehicle stops. The graph 610 of FIG. 6A and the graph 620 of FIG. 6B show respective stopping distances corresponding to different road conditions. For example, stopping distances on a dry paved road are represented in the graph 610 and stopping distances on a frozen road are represented in the graph 620. A controller determines a stopping distance of the vehicle based on a driving situation including a road condition, and determines a parameter associated with a width of a stereo camera based on the stopping distance. Also, the reaction distance may be changed based on a reaction speed of the controller or a user. For example, with users, the controller may calculate the reaction distances for individual users, and determine the appropriate parameter associated with the width of the stereo camera based on the appropriate reaction distance. When the user implements the decelerating manipulation, the autonomous vehicle may be monitoring and performing recognition operations for the surroundings of the vehicle for providing alerts, such as collision or obtrusion alerts, to the user or for other information provisions, such as on a display, instrument cluster, or heads up display of the vehicle. The user may initiate the decelerating

manipulation based on such alerts, such as when the autonomous vehicle detects an obtrusion before visually observed by the user.

[0039] FIG. 7 illustrates an example of a controlling of a width of a stereo camera based on a stopping distance. FIG. 7 illustrates a maximum measurable depth Z_1, a depth error ΔZ_1 of the maximum measurable depth Z_1, a maximum measurable depth Z_2, a depth error ΔZ_2 of the maximum measurable depth Z_2, and a stopping distance. In the example of FIG. 7, a stereo camera width D_1 is less than a stereo camera width D_2, the maximum measurable depth Z_1 corresponds to the stereo camera width D_1, the maximum measurable depth Z_2 corresponds to the stereo camera width D_2. As described with reference to FIGS. 6A and 6B, the stopping distance is determined based on the driving situation including a driving speed of the vehicle, the road condition, and reaction speed of a user, for example. Also, it may be desirable for the safe distance to be greater than or equal to the stopping distance. Such a constraint associated with the safe distance may be represented by the below Equation 5, for example.

Equation 5:

$$Z - \Delta Z \geq \mathrm{SD}$$

[0040] In Equation 5, $Z - \Delta Z$ indicates the safe distance and SD denotes the stopping distance. A controller, such as any of the controllers of FIGS. 1-3 and 9, may determine a minimum value of a parameter associated with a width of a stereo camera according to Equation 5, i.e., a minimum value of the parameter for the stereo camera that results in the stereo camera width that provides a maximum measurable Z such that $Z - \Delta Z$ is greater than or equal to the stopping distance. The controller may determine the parameter to have a value greater than or equal to the minimum value. As further discussed below, the controller may also determine a maximum value for the parameter based on another constraint that is associated with a threshold blind spot distance and set the parameter for the stereo camera to have a value between the minimum value and the maximum value.

[0041] Referring to the example of FIG. 7, the autonomous driving apparatus has the maximum measurable depth Z_1, with the corresponding depth error ΔZ_1, based on the stereo camera width D_1. In this example, the safe distance $Z_1 - \Delta Z_1$ is demonstrated as being less than the illustrated stopping distance, which may result a greater probability of an accident. Thus, the autonomous driving apparatus may increase the width of the stereo camera to secure a greater safe distance. For example, when the autonomous vehicle increases the stereo camera width from D_1 to D_2, the autonomous driving apparatus obtains a minimum safe distance $Z_2 - \Delta Z_2$, which is greater than or equal to the stopping distance.

[0042] In addition, in one or more embodiments, when the driving situation is estimated to be the vehicle driving at a highest speed range, of plural defined speed ranges, for example, to secure a greatest measurable depth the minimum value for the parameter may correspond to the width of the stereo camera being automatically set to the greatest width available, such as by any of the capturers of FIGS. 1-3 and 9, e.g., thereby prioritizing greater maximum measurable depth and lesser maximum depth error over the corresponding increase in extents of the blind spot areas. Conversely, in one or more embodiments, when the driving situation is the vehicle driving at a low or lowest speed range, of such plural defined speed ranges, to secure a wide viewing area the maximum value for the parameter may correspond to the width of the stereo camera being automatically set to the minimum width available, such as by any of the capturers of FIGS. 1-3 and 9, e.g., thereby prioritizing a minimizing of the extents of the blind spot areas over the corresponding decrease in maximum measurable depth and increased maximum depth error.

[0043] FIG. 8 illustrates an example of a controlling a width of a stereo camera based on a threshold blind spot distance. FIG. 8 illustrates a depth-measured area and a blind spot distance. As discussed in the foregoing explanation, the blind spot distance increases according to an increase in a width of a stereo camera. Since the blind spot distance exerts influence on recognizing a situation of an adjacent lane, an appropriate blind spot distance may desirably be secured based on a driving situation of a vehicle. A controller determines a threshold blind spot distance based on the driving situation of the vehicle. The threshold blind spot distance indicates an example minimum distance for, or maximum extent of, a blind spot area for measuring a distance between the vehicle and an object located on an adjacent lane based on the driving situation.

[0044] For example, when driving at high speed, the probabilities of changing lanes, changing direction, or sudden obtrusions of another vehicle may be relatively low. Thus, the controller may set a relatively long threshold blind spot distance for the driving situation when the vehicle is driving at high speed when compared to the driving situation when the vehicle is driving at low speed. Also, since a wide visual field may be desirably secured in the driving situation when the vehicle is driving at low speed, driving in a city, and a driving in cloudy weather, the controller may decrease the threshold blind spot distance compared to the relatively long threshold blind spot distance for the driving situation when the vehicle is driving at high speed. To obtain an appropriate visual field corresponding to the driving situation, it may be desirable for an actual blind spot distance to be less than the threshold blind spot distance set for that driving situation. Such a constraint associated with the threshold blind spot distance may be expressed by the below Equation 6, for

example.

Equation 6:

$$BD_{TH} \geq BD_{A}$$

[0045] In Equation 6, BD_{TH} denotes the threshold blind spot distance, and BD_{A} denotes the actual blind spot distance. Thus, in one or more embodiments, the controller may determine a maximum value of a parameter associated with the width of the stereo camera using Equation 6. In such an example, the controller determines the parameter associated with the width of the stereo camera such that the parameter has a value less than or equal to the determined maximum value. As noted above, the controller may also determine a minimum value of the parameter associated with the width of the stereo camera based on a different constraint associated with the aforementioned safe distance, and, thus, determine or set the parameter associated with the width of the stereo camera to be a final value, for example, between the maximum value and the minimum value.

[0046] In the example of FIG. 8, the actual or current blind spot distance is illustrated as being greater than the illustrated threshold blind spot distance. For example, the controller may have decreased the threshold blind spot distance from a previous greater threshold blind spot distance in response to a determined change in lane or direction, sensed other vehicle movement or obtrusion, or a change in a weather condition. In this example, the illustrated threshold blind spot distance may, thus, have been decreased to be less than the actual or current blind spot distance. Accordingly, the controller may decrease the width of the stereo camera to adjust the actual blind spot distance so as to be less than or equal to the illustrated threshold blind spot distance. Through such an adjustment of the width of the stereo camera, an autonomous driving apparatus obtains an appropriate visual field corresponding to a current determined driving situation.

[0047] FIG. 9 illustrates an example of an autonomous driving apparatus. Referring to FIG. 9, an autonomous driving vehicle 950 is or includes an autonomous driving apparatus 900, such as any of the autonomous driving apparatuses of FIGS. 1-3. Here, it is also noted that the autonomous driving apparatus 900 may be, or may be included in, an automobile or truck, as well as a motorcycle, 3 wheel vehicle, or a drone that can fly or operate underwater. The autonomous driving apparatus 900 includes multiple capturers 910, a controller 920, one or more sensors 930, and one or more communicators 940. In an example, the controller 920 is representative of one or more processors or a vehicle control module, as only an example, including such one or more processors configured to perform any one or more or all of the operations described herein. In another example, the controller 920 may be representative of such one or more processors and one or more memories configured to store instructions to control the one or more processors to execute such instructions to implement such operations and/or store or cache received sensor or external sensor or device information or corresponding estimated driving situation determinations. The memory may alternatively or additionally be configured elsewhere within the autonomous driving apparatus, noting that depending on embodiment the autonomous driving apparatus may be the vehicle, a system less than the vehicle, or merely one or more such controller(s) 920. Briefly, though an example of the controller 920 operating through such one or more processors has been described, embodiments also include the controller performing one or more or all of such operations through hardware other than such processors. The capturers 910 may respectively include cameras to perform capturing in at least one of a front direction, a rear direction, or a side direction. For example, the illustrated example two capturers 910 of FIG. 9 use respective cameras to perform capturing in the front direction and the rear direction, or capturing in the front direction, the rear direction, and/or one or more side directions, e.g., according to the aforementioned discussions regarding FIGS. 2 and/or 3, as only examples. The capturers 910 may be disposed at various positions for example, on a periphery of a loop panel of the autonomous driving vehicle 950, noting that alternative arrangements are also available. The foregoing descriptions regarding FIGS. 1-8 are also applicable to the capturers 910, though embodiments are not limited thereto. The sensor 930 generates situation information for estimating a driving situation of the autonomous driving vehicle 950 and may transmit the situation information to the controller 920. The communicator 940 may receive situation information from a device external to the autonomous driving vehicle 950 and transmit the received situation information to the controller 920.

[0048] The controller 920 estimates the driving situation of the autonomous driving vehicle 950 and determines a parameter associated with a width for a stereo camera based on the driving situation. The controller 920 controls at least one of the capturers 910 such that two cameras included in the corresponding capturer(s) 910 have a distance therebetween corresponding to the determined parameter. When performing capturing in at least two directions, the controller 920 may control different camera pairs on the same capturer 910 or different cameras on different capturers 910 based on different parameters or the same parameter. For example, one of the capturers 910 performs the capturing in the front direction and the rear direction, e.g., using respective stereo cameras, or a stereo camera of one of the capturers 910 performs the capturing in the front direction and a stereo camera of another of the capturers 910 performs

capturing in the rear direction. The controller 920 may determine a parameter P associated with a width of the corresponding stereo camera based on an estimated driving situation, and control the respective capturers 910 such that the corresponding two cameras of the stereo camera performing the capturing in the front direction have a distance therebetween corresponding to the parameter P and the corresponding two cameras of the stereo camera performing the capturing in the rear directions have a distance therebetween corresponding to the parameter P. Here, though the same parameter P is shown as being applied to forward and rearward image capturing, respective different parameters may be determined as discussed above for each stereo camera based on respective preset driving situation dependent maximum measurement distances and/or threshold blind spot distances, as only examples. In the example where the same parameter P is used for the front and rear image capturing, a visual field of at least a maximum measurable depth, a safe distance, and a threshold blind spot distance may be secured in the rear direction, for example.

[0049] FIG. 10 illustrates an example of an autonomous driving method. Referring to FIG. 10, in operation 1010, an autonomous driving apparatus, for example, acquires and/or estimates a driving situation of a vehicle. In operation 1020, the autonomous driving apparatus determines a parameter associated with a width of a stereo camera based on the estimated driving situation. In operation 1030, the autonomous driving apparatus controls a capturer performing capturing in a first direction such that two cameras included in the capturer are controlled to be separated by a distance corresponding to the parameter. In operation 1040, the autonomous driving apparatus measures a depth of an object located in the first direction based on output images of the two cameras. Since any or all of the foregoing descriptions are also applicable here, further repeated descriptions about the autonomous driving method will be omitted.

[0050] The capturer 110, controller 120, capturer 210, cameras 215, controller 220, capturer 310, cameras 315, controller 320, capturer 910, controller 920, sensor(s) 920, and communicator(s) 940, for example, in FIGS. 1-5 and 9 that perform the operations described in this application are implemented by hardware components configured to perform the operations described in this application that are performed by the hardware components. Examples of hardware components that may be used to perform the operations described in this application where appropriate include controllers, sensors, generators, drivers, memories, comparators, arithmetic logic units, adders, subtractors, multipliers, dividers, integrators, optical sensors, and any other electronic components configured to perform the operations described in this application. In other examples, one or more of the hardware components, such as any of the controllers, sensors, and communicators, that perform the operations described in this application are implemented by computing hardware, for example, by one or more processors or computers. A processor or computer may be implemented by one or more processing elements, such as an array of logic gates, a controller and an arithmetic logic unit, a digital signal processor, a microcomputer, a programmable logic controller, a field-programmable gate array, a programmable logic array, a microprocessor, or any other device or combination of devices that is configured to respond to and execute instructions in a defined manner to achieve a desired result. In one example, a processor or computer includes, or is connected to, one or more memories storing instructions or software that are executed by the processor or computer. Hardware components implemented by a processor or computer may execute instructions or software, such as an operating system (OS) and one or more software applications that run on the OS, to perform the operations described in this application. The hardware components may also access, manipulate, process, create, and store data in response to execution of the instructions or software. For simplicity, the singular term "processor" or "computer" may be used in the description of the examples described in this application, but in other examples multiple processors or computers may be used, or a processor or computer may include multiple processing elements, or multiple types of processing elements, or both. For example, a single hardware component or two or more hardware components may be implemented by a single processor, or two or more processors, or a processor and a controller. One or more hardware components may be implemented by one or more processors, or a processor and a controller, and one or more other hardware components may be implemented by one or more other processors, or another processor and another controller. One or more processors, or a processor and a controller, may implement a single hardware component, or two or more hardware components. A hardware component may have any one or more of different processing configurations, examples of which include a single processor, independent processors, parallel processors, single-instruction single-data (SISD) multiprocessing, single-instruction multiple-data (SIMD) multiprocessing, multiple-instruction single-data (MISD) multiprocessing, and multiple-instruction multiple-data (MIMD) multiprocessing.

[0051] In one or more embodiments, the methods and processes illustrated in FIGS. 1-10 that perform the operations described in this application are performed by computing hardware, for example, by one or more processors or computers, implemented as described above executing instructions or software to perform the operations described in this application that are performed by the methods. For example, a single operation or two or more operations may be performed by a single processor, or two or more processors, or a processor and a controller. One or more operations may be performed by one or more processors, or a processor and a controller, and one or more other operations may be performed by one or more other processors, or another processor and another controller. One or more processors, or a processor and a controller, may perform a single operation, or two or more operations.

[0052] Instructions or software to control computing hardware, for example, one or more processors or computers, to implement the hardware components and perform the methods as described above may be written as computer programs,

code segments, instructions or any combination thereof, for individually or collectively instructing or configuring the one or more processors or computers to operate as a machine or special-purpose computer to perform the operations that are performed by the hardware components and the methods as described above. In one example, the instructions or software include machine code that is directly executed by the one or more processors or computers, such as machine code produced by a compiler. In another example, the instructions or software includes higher-level code that is executed by the one or more processors or computer using an interpreter. The instructions or software may be written using any programming language based on the block diagrams and the flow charts illustrated in the drawings and the corresponding descriptions in the specification, which disclose algorithms for performing the operations that are performed by the hardware components and the methods as described above.

[0053] The instructions or software to control computing hardware, for example, one or more processors or computers, to implement the hardware components and perform the methods as described above, and any associated data, data files, and data structures, may be recorded, stored, or fixed in or on one or more non-transitory computer-readable storage media. Examples of a non-transitory computer-readable storage medium include read-only memory (ROM), random-access memory (RAM), flash memory, CD-ROMs, CD-Rs, CD+Rs, CD-RWs, CD+RWs, DVD-ROMs, DVD-Rs, DVD+Rs, DVD-RWs, DVD+RWs, DVD-RAMs, BD-ROMs, BD-Rs, BD-R LTHs, BD-REs, magnetic tapes, floppy disks, magneto-optical data storage devices, optical data storage devices, hard disks, solid-state disks, and any other device that is configured to store the instructions or software and any associated data, data files, and data structures in a non-transitory manner and provide the instructions or software and any associated data, data files, and data structures to one or more processors or computers so that the one or more processors or computers can execute the instructions. In one example, the instructions or software and any associated data, data files, and data structures are distributed over network-coupled computer systems so that the instructions and software and any associated data, data files, and data structures are stored, accessed, and executed in a distributed fashion by the one or more processors or computers.

[0054] While this disclosure includes specific examples, it will be apparent after an understanding of the disclosure of this application that various changes in form and details may be made in these examples without departing from scope of the claims. The examples described herein are to be considered in a descriptive sense only, and not for purposes of limitation. Descriptions of features or aspects in each example are to be considered as being applicable to similar features or aspects in other examples. Suitable results may be achieved if the described techniques are performed in a different order, and/or if components in a described system, architecture, device, or circuit are combined in a different manner, and/or replaced or supplemented by other components. Therefore, the scope of the invention is defined not by the detailed description, but by the claims.

Claims

1. A method for autonomously driving an automobile (950), comprising:

estimating a driving situation of the automobile (950);
determining a parameter to control a camera array (215) based on the estimated driving situation, said camera array comprising at least three cameras (215) facing a first direction and arranged on said automobile at preset intervals from each other;
controlling a capturer (110, 210, 910) configured to select two cameras (215) of the camera array so as to have a desired distance therebetween, said distance being based on the determined parameter, said two selected cameras forming a stereo camera; and
measuring a depth of an object located in the first direction based on two images respectively captured by the selected two cameras (215) with the desired distance,
detecting another vehicle or an obstacle in the first direction;
CHARACTERISED IN THAT the controlling of the capturer (110, 210, 910) further comprises:

assigning a priority to a side of the camera array based on the detected another vehicle or obstacle;
selecting said two cameras (215) from the camera array is based further on the assigned priority, such that a centerline of the two selected cameras is positioned in a direction, relative to the centerline of the camera array, of the side of the camera array to which the priority has been assigned; and
operating remaining cameras of the camera array other than the selected two cameras in a standby or power off mode.

2. The method of claim 1, wherein the plurality of cameras (215) are fixedly arranged in the capturer (110, 210, 910) and each linearly separated by a first distance, and the distance (D) corresponding to the determined parameter is evenly divisible by the first distance.

3. The method of any of the previous claims 1-2, wherein the estimated driving situation is furthermore determined based on at least one of a moving direction of the automobile (950), a location of the automobile (950), or a user manipulation.

4. The method of any of the previous claims 1-3, further comprising:

predicting a driving direction of the automobile (950) based on an estimated driving situation,
wherein the determining of the parameter includes determining the parameter based on a visual field direction of the camera array corresponding to the predicted driving direction, further comprising selectively turning off one or more additional cameras of the automobile (950) respectively for one or more other visual field directions that are determined not needed for driving of the automobile (950) in the predicted driving direction.

5. The method of any of the previous claims 1-4, further comprising:

controlling the capturer (110, 210, 310, 910) or another capturer so that two additional cameras perform stereo capturing in a second direction, opposite to the first direction, with a stereo camera having a distance between said two additional cameras based on the determined parameter; and
measuring a depth of an object located in the second direction based on output images of the two additional cameras,
wherein the capturer (110, 210, 310, 910) or the other capturer is configured to perform capturing in the second direction in coordination with the captured two images in the first direction.

6. A non-transitory computer-readable storage medium storing instructions that, when executed by a processor in an autonomous driving apparatus (900) according to claim 7, cause the processor to perform the method of claim 1.

7. An autonomous driving apparatus (900), the apparatus comprising:

a capturer comprising a camera array;
a processor configured to:

estimate the driving situation of an automobile;
determine a parameter to control a camera array (215) based on the estimated driving situation of the automobile (950), said camera array comprising at least three cameras (215) facing a first direction and arranged on said automobile (950) at preset intervals (D) from each other,
control a capturer (110, 210, 910) configured to select two cameras (215) of the camera array so as to have a desired distance therebetween, said distance being based on the determined parameter, said two selected cameras forming a stereo camera,
measure a depth of an object located in the first direction based on two images respectively captured by the selected two cameras (215) with the desired distance, and
detect another vehicle or an obstacle in the first direction;
CHARACTERISED IN THAT the processor is further configured to:

assign a priority to a side of the camera array based on the detected another vehicle or obstacle;
select said two cameras (215) from the camera array based further on the assigned priority, such that a centerline of the two selected cameras is positioned in a direction, relative to the centerline of the camera array, of the side of the stereo camera to which the priority has been assigned; and
operate remaining cameras of the camera array other than the selected two cameras in a standby or power off mode.

8. The apparatus of claim 7, the capturer (110, 210, 910) being configured to control arrangement between the two cameras (215), and wherein the processor is configured to control the capturer (110, 210, 910) to rotate at least one of the two selected cameras (215) in a prioritized direction corresponding to a direction indicated by a user manipulation of a turn signal level of the automobile (950) or based on which of left or right turn signal indicators are activated in the automobile (950).

9. The apparatus of any of the previous claims 7-8, wherein the processor is further configured to determine the estimated driving situation based on sensed information or one or more driving situation estimations from sensors of the automobile (950) and/or from sensors or devices external of the automobile (950).

10. The apparatus of any of the previous claims 7-9, wherein the processor is further configured to determine surrounding environment information of the automobile (950) based on the measured depth and to control the determined surrounding environment information to be displayed on a display of the automobile (950).

Patentansprüche

1. Verfahren zum autonomen Fahren eines Automobils (950), wobei das Verfahren Folgendes umfasst:

Schätzen einer Fahrsituation des Automobils (950);
Bestimmen eines Parameters zum Steuern einer Kameraanordnung (215) basierend auf der geschätzten Fahrsituation, wobei die Kameraanordnung mindestens drei Kameras (215) umfasst, die in eine erste Richtung zeigen und in voreingestellten Abständen voneinander an dem Automobil angeordnet sind;
Steuern eines Aufnehmers (110, 210, 910), der so konfiguriert ist, dass er zwei Kameras (215) der Kameraanordnung so auswählt, dass zwischen ihnen ein gewünschter Abstand besteht,
wobei der Abstand auf dem bestimmten Parameter basiert, wobei die zwei ausgewählten Kameras eine Stereokamera bilden; und
Messen einer Tiefe eines Objekts, das sich in der ersten Richtung befindet, basierend auf zwei Bildern, die jeweils von den ausgewählten zwei Kameras (215) mit dem gewünschten Abstand aufgenommen wurden,
Erfassen eines anderen Fahrzeugs oder eines Hindernisses in der ersten Richtung;
DADURCH GEKENNZEICHNET, DASS das Steuern des Aufnehmers (110, 210, 910) ferner Folgendes umfasst:

Zuweisen einer Priorität zu einer Seite der Kameraanordnung basierend auf dem erfassten anderen Fahrzeug oder Hindernis;
Auswählen der zwei Kameras (215) aus der Kameraanordnung ferner basierend auf der zugewiesenen Priorität, so dass eine Mittellinie der zwei ausgewählten Kameras relativ zu der Mittellinie des Kameraanordnung in einer Richtung der Seite der Kameraanordnung positioniert ist, der die Priorität zugewiesen wurde; und
Betreiben der verbleibenden Kameras der Kameraanordnung außer den ausgewählten zwei Kameras in einem Standby- oder Abschaltmodus.

2. Verfahren nach Anspruch 1, wobei die Vielzahl von Kameras (215) in dem Aufnehmer (110, 210, 910) fest angeordnet und jeweils durch einen ersten Abstand linear getrennt sind und der Abstand (D), der dem bestimmten Parameter entspricht, gleichmäßig durch die erste Distanz teilbar ist.

3. Verfahren nach einem der vorhergehenden Ansprüche 1 und 2, wobei die geschätzte Fahrsituation ferner basierend auf mindestens einem von einer Bewegungsrichtung des Automobils (950), einer Position des Automobils (950) oder einer Benutzermanipulation bestimmt wird.

4. Verfahren nach einem der vorhergehenden Ansprüche 1 bis 3, das ferner Folgendes umfasst:

Vorhersagen einer Fahrtrichtung des Automobils (950) basierend auf der geschätzten Fahrsituation,
wobei das Bestimmen des Parameters das Bestimmen des Parameters basierend auf einer Sichtfeldrichtung der Kameraanordnung beinhaltet, die der vorhergesagten Fahrtrichtung entspricht, femer umfassend das selektive Ausschalten einer oder mehrerer zusätzlicher Kameras des Automobils (950) jeweils für eine oder mehrere andere Sichtfeldrichtungen, die zum Fahren des Automobils (950) in der vorhergesagten Fahrtrichtung als nicht erforderlich bestimmt werden.

5. Verfahren nach einem der vorhergehenden Ansprüche 1 bis 4, das femer Folgendes umfasst:

Steuern des Aufnehmers (110, 210, 310, 910) oder eines anderen Aufnehmers, so dass zwei zusätzliche Kameras eine Stereoaufnahme in einer zweiten Richtung durchführen, die der ersten Richtung entgegengesetzt ist, wobei eine Stereokamera einen auf dem erfassten Parameter basierenden Abstand zwischen den zwei zusätzlichen Kameras aufweist; und
Messen einer Tiefe eines Objekts, das sich in der zweiten Richtung befindet, basierend auf Ausgabebildern der zwei zusätzlichen Kameras,
wobei der Aufnehmer (110, 210, 310, 910) oder der andere Aufnehmer so konfiguriert ist, dass er ein Aufnehmen

in der zweiten Richtung in Koordination mit den in der ersten Richtung aufgenommenen zwei Bildern durchführt.

6. Nicht flüchtiges, computerlesbares Medium, auf dem Anweisungen gespeichert sind, die, wenn sie von einem Prozessor in einer autonomem Fahrvorrichtung (900) nach Anspruch 7 ausgeführt werden, den Prozessor dazu veranlassen, das Verfahren nach Anspruch 1 durchzuführen.

7. Autonome Fahrvorrichtung (900), wobei die Vorrichtung Folgendes umfasst:

einen Aufnehmer, der eine Kameraanordnung umfasst;
einen Prozessor, der zu Folgendem konfiguriert ist:

Schätzen der Fahrsituation eines Automobils,
Bestimmen eines Parameters zum Steuern einer Kameraanordnung (215) basierend auf der geschätzten Fahrsituation des Automobils (950), wobei die Kameraanordnung mindestens drei Kameras (215) umfasst, die in eine erste Richtung zeigen und in voreingestellten Abständen (D) voneinander an dem Automobil (950) angeordnet sind;
Steuern eines Aufnehmers (110, 210, 910), der so konfiguriert ist, dass er zwei Kameras (215) der Kameraanordnung so auswählt, dass zwischen ihnen ein gewünschter Abstand besteht, wobei der Abstand auf dem bestimmten Parameter basiert, wobei die zwei ausgewählten Kameras eine Stereokamera bilden, und
Messen einer Tiefe eines Objekts, das sich in der ersten Richtung befindet, basierend auf zwei Bildern, die jeweils von den ausgewählten zwei Kameras (215) mit dem gewünschten Abstand aufgenommen wurden, und
Erfassen eines anderen Fahrzeugs oder eines Hindernisses in der ersten Richtung;
DADURCH GEKENNZEICHNET, DASS der Prozessor ferner zu Folgendem konfiguriert ist:

Zuweisen einer Priorität zu einer Seite der Kameraanordnung basierend auf dem erfassten anderen Fahrzeug oder Hindernis;
Auswählen der zwei Kameras (215) aus der Kameraanordnung ferner basierend auf der zugewiesenen Priorität, so dass eine Mittellinie der zwei ausgewählten Kameras relativ zu der Mittellinie des Kameraanordnung in einer Richtung der Seite des Kameraanordnung positioniert ist, der die Priorität zugewiesen wurde; und
Betreiben der verbleibenden Kameras der Kameraanordnung außer den ausgewählten zwei Kameras in einem Standby- oder Abschaltmodus.

8. Vorrichtung nach Anspruch 7, wobei der Aufnehmer (110, 210, 910) so konfiguriert ist, dass er die Anordnung zwischen den zwei Kameras (215) steuert, und wobei der Prozessor so konfiguriert ist, dass er den Aufnehmer (110, 210, 910) steuert, um mindestens eine der zwei ausgewählten Kameras (215) in eine priorisierte Richtung zu drehen, die einer Richtung entspricht, die durch eine Benutzerbetätigung eines Blinkerhebels des Automobils (950) angezeigt wird oder basierend darauf, welcher des linken oder rechten Fahrtrichtungsanzeigers in dem Automobil (950) aktiviert ist.

9. Vorrichtung nach einem der vorhergehenden Ansprüche 7 und 8, wobei der Prozessor ferner dazu konfiguriert ist, die geschätzte Fahrsituation basierend auf erfassten Informationen oder einer oder mehreren Fahrsituationsschätzungen von Sensoren des Automobils (950) und/oder von Sensoren oder Vorrichtungen außerhalb des Automobils (950) zu bestimmen.

10. Vorrichtung nach einem der vorhergehenden Ansprüche 7 bis 9, wobei der Prozessor ferner dazu konfiguriert ist, Umgebungsinformationen des Automobils (950) basierend auf der gemessenen Tiefe zu bestimmen und eine derartige Steuerung durchzuführen, dass die bestimmten Umgebungsinformationen auf einer Anzeige des Automobils (950) angezeigt werden.

Revendications

1. Procédé de conduite autonome d'une automobile (950), comprenant :

l'estimation d'une situation de conduite de l'automobile (950),

la détermination d'un paramètre servant à la commande d'un ensemble de caméras (215) compte tenu de la situation de conduite estimée, ledit ensemble de caméras comprenant au moins trois caméras (215) tournées dans une première direction et agencées sur ladite automobile à intervalles prédéfinis,
la commande d'un organe de prise de vues (110, 210, 910) conçu pour sélectionner deux caméras (215) de l'ensemble de caméras de façon à produire une distance souhaitée entre elles, ladite distance reposant sur le paramètre déterminé, lesdites deux caméras sélectionnées formant une caméra stéréoscopique,
la mesure de la profondeur d'un objet situé dans la première direction compte tenu de deux images respectivement prises par les deux caméras (215) sélectionnées présentant la distance souhaitée, et
la détection d'un autre véhicule ou d'un obstacle dans la première direction ;
CARACTÉRISÉ EN CE QUE la commande de l'organe de prise de vues (110, 210, 910) comprend en outre :

l'attribution d'une priorité à un côté de l'ensemble de caméras compte tenu de la détection de l'autre véhicule ou de l'obstacle,
la sélection desdites deux caméras (215) au sein de l'ensemble de caméras compte tenu en outre de la priorité attribuée, de telle manière qu'une ligne médiane entre les deux caméras sélectionnées soit disposée, par rapport à la ligne médiane de l'ensemble de caméras, vers le côté de l'ensemble de caméras auquel la priorité a été attribuée, et
le passage des caméras restantes de l'ensemble de caméras, autres que les deux caméras sélectionnées, à un mode de veille ou éteint.

2. Procédé selon la revendication 1, dans lequel la pluralité de caméras (215) sont agencées fixes dans l'organe de prise de vues (110, 210, 910) et sont chacune espacées, de façon linéaire, selon une première distance, et la distance (D) correspondant au paramètre déterminé est un multiple de la première distance.

3. Procédé selon l'une quelconque des revendications précédentes 1 et 2, dans lequel la situation de conduite estimée est de surcroît déterminée compte tenu du sens de déplacement de l'automobile (950), de l'emplacement de l'automobile (950) et/ou d'une manipulation effectuée par l'utilisateur.

4. Procédé selon l'une quelconque des revendications précédentes 1 à 3, comprenant en outre :

la prévision de la direction d'avancée de l'automobile (950) compte tenu de la situation de conduite estimée ;
ladite détermination du paramètre comprenant la détermination du paramètre compte tenu de la direction du champ visuel de l'ensemble de caméras correspondant à la direction d'avancée prévue ; le procédé comprenant en outre la désactivation sélective d'une ou plusieurs caméras supplémentaires de l'automobile (950) respectivement associées à une ou plusieurs autres directions de champ visuel ayant été déterminées non utiles pour la conduite de l'automobile (950) dans la direction d'avancée prévue.

5. Procédé selon l'une quelconque des revendications précédentes 1 à 4, comprenant en outre :

la commande de l'organe de prise de vues (110, 210, 310, 910) ou d'un autre organe de prise de vues de telle façon que deux caméras supplémentaires effectuent une prise de vues stéréoscopique dans une deuxième direction, opposée à la première direction, à l'aide d'une caméra stéréoscopique dont la distance entre lesdites deux caméras supplémentaires est fonction du paramètre déterminé, et
la mesure de la profondeur d'un objet situé dans la deuxième direction compte tenu d'images produites par les deux caméras supplémentaires ;
ledit organe de prise de vues (110, 210, 310, 910) ou l'autre organe de prise de vues étant conçu pour effectuer la prise de vues dans la deuxième direction en coordination avec les deux images prises dans la première direction.

6. Support d'enregistrement non transitoire lisible par ordinateur sur lequel sont stockées des instructions qui, lorsqu'elles sont exécutées par un processeur dans un dispositif de conduite autonome (900) selon la revendication 7, amènent le processeur à mettre en œuvre le procédé selon la revendication 1.

7. Dispositif de conduite autonome (900), comprenant :

un organe de prise de vues comprenant un ensemble de caméras,
un processeur conçu pour :

estimer la situation de conduite d'une automobile,
déterminer un paramètre servant à la commande d'un ensemble de caméras (215) compte tenu de la situation de conduite estimée de l'automobile (950), ledit ensemble de caméras comprenant au moins trois caméras (215) tournées dans une première direction et agencées sur ladite automobile (950) à intervalles (D) prédéfinis,
commander un organe de prise de vues (110, 210, 910) conçu pour sélectionner deux caméras (215) de l'ensemble de caméras de façon à produire une distance souhaitée entre elles, ladite distance reposant sur le paramètre déterminé, lesdites deux caméras sélectionnées formant une caméra stéréoscopique, et mesurer la profondeur d'un objet situé dans la première direction compte tenu de deux images respectivement prises par les deux caméras (215) sélectionnées présentant la distance souhaitée, et
détecter un autre véhicule ou un obstacle dans la première direction ;
CARACTÉRISÉ EN CE QUE le processeur est conçu en outre pour :

attribuer une priorité à un côté de l'ensemble de caméras compte tenu de la détection de l'autre véhicule ou de l'obstacle,
sélectionner lesdites deux caméras (215) au sein de l'ensemble de caméras compte tenu en outre de la priorité attribuée, de telle manière qu'une ligne médiane entre les deux caméras sélectionnées soit disposée, par rapport à la ligne médiane de l'ensemble de caméras, vers le côté de l'ensemble de caméras auquel la priorité a été attribuée, et
faire passer les caméras restantes de l'ensemble de caméras, autres que les deux caméras sélectionnées, à un mode de veille ou éteint.

8. Dispositif selon la revendication 7, l'organe de prise de vues (110, 210, 910) étant conçu pour commander l'agencement entre les deux caméras (215), et le processeur étant conçu pour commander l'organe de prise de vues (110, 210, 910) de façon qu'il fasse tourner au moins une des deux caméras (215) sélectionnées dans une direction ayant la priorité et correspondant à une direction indiquée par une manipulation, par l'utilisateur, d'un levier de clignotant de l'automobile (950) ou par celui des clignotants, droit ou gauche, qui a été activé dans l'automobile (950).

9. Dispositif selon l'une quelconque des revendications précédentes 7 et 8, dans lequel le processeur est conçu en outre pour déterminer la situation de conduite estimée compte tenu d'informations détectées ou d'une ou plusieurs estimations de situation de conduite en provenance de capteurs de l'automobile (950) et/ou de capteurs ou d'appareils externes à l'automobile (950).

10. Dispositif selon l'une quelconque des revendications précédentes 7 à 9, dans lequel le processeur est conçu en outre pour déterminer des informations relatives à l'environnement de l'automobile (950) compte tenu de la profondeur mesurée et pour commander l'affichage, sur un écran de l'automobile (950), des informations déterminées relatives à l'environnement.

FIG. 1

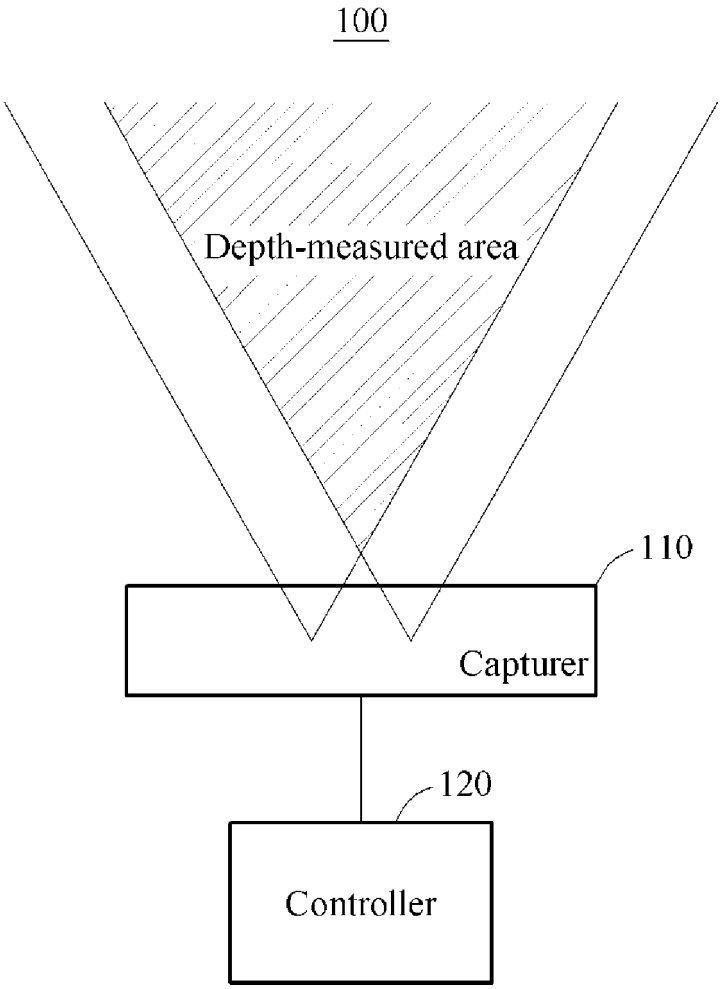


FIG. 2

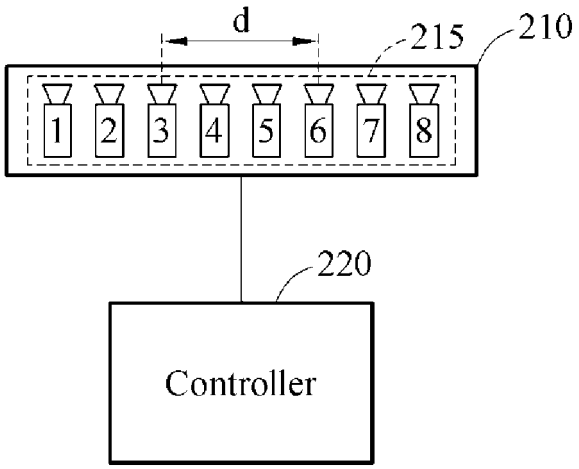


FIG. 3

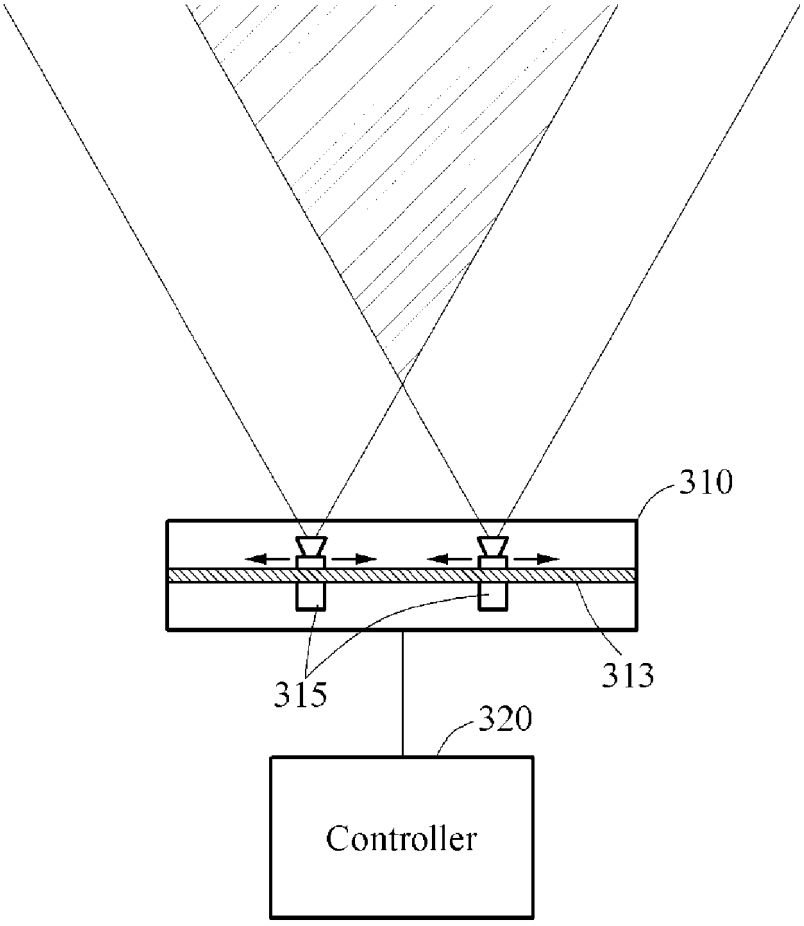


FIG. 4

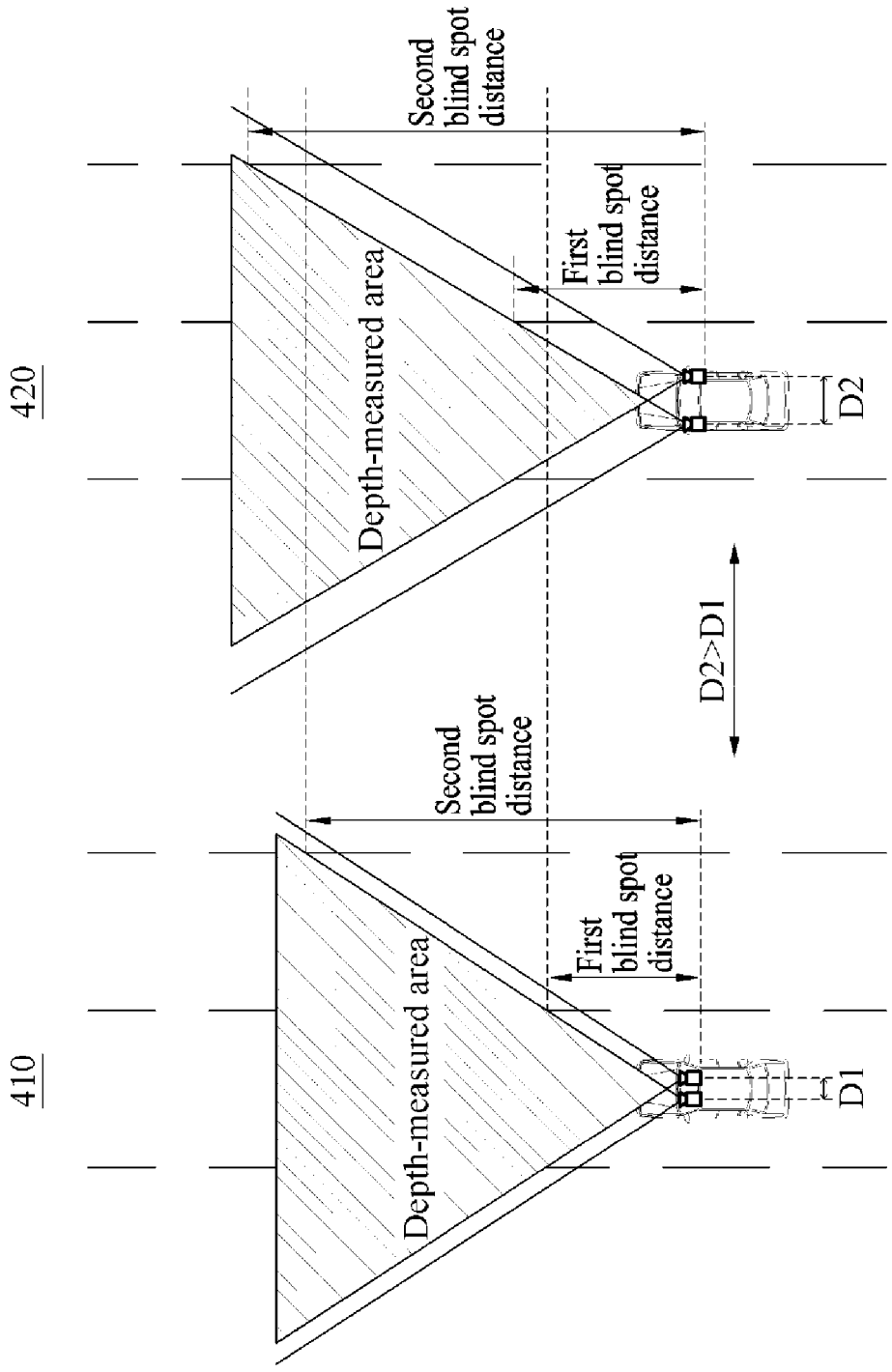

420
Second blind spot distance
First blind spot distance
Depth-measured area
D2
D2>D1
410
Second blind spot distance
First blind spot distance
Depth-measured area
D1

FIG. 5

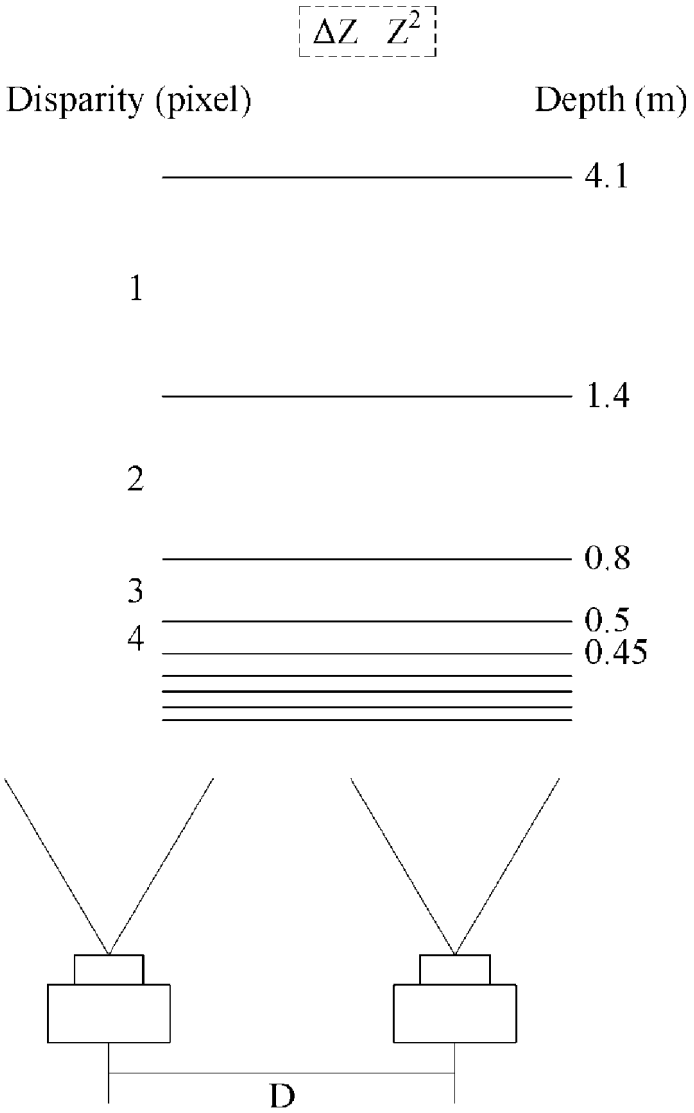


FIG. 6A

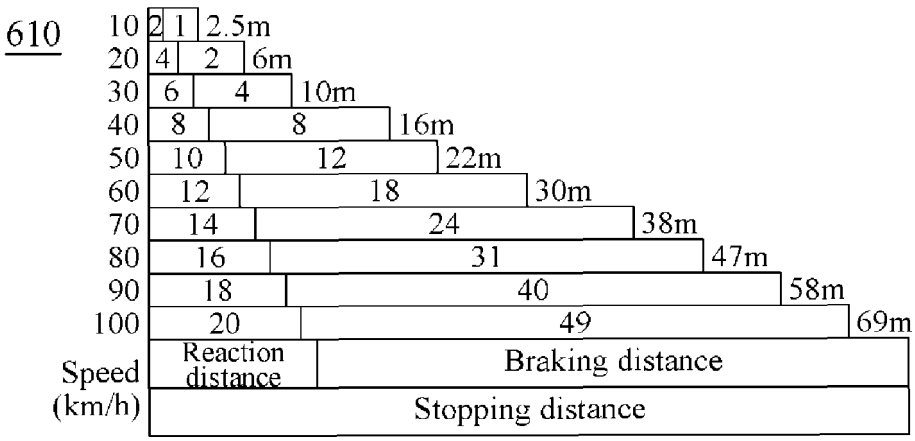

610
10
20
30
40
50
60
70
80
90
100
Speed (km/h)
2
1
2.5m
4
2
6m
6
4
10m
8
8
16m
10
12
22m
12
18
30m
14
24
38m
16
31
47m
18
40
58m
20
49
69m
Reaction distance
Braking distance
Stopping distance

FIG. 6B

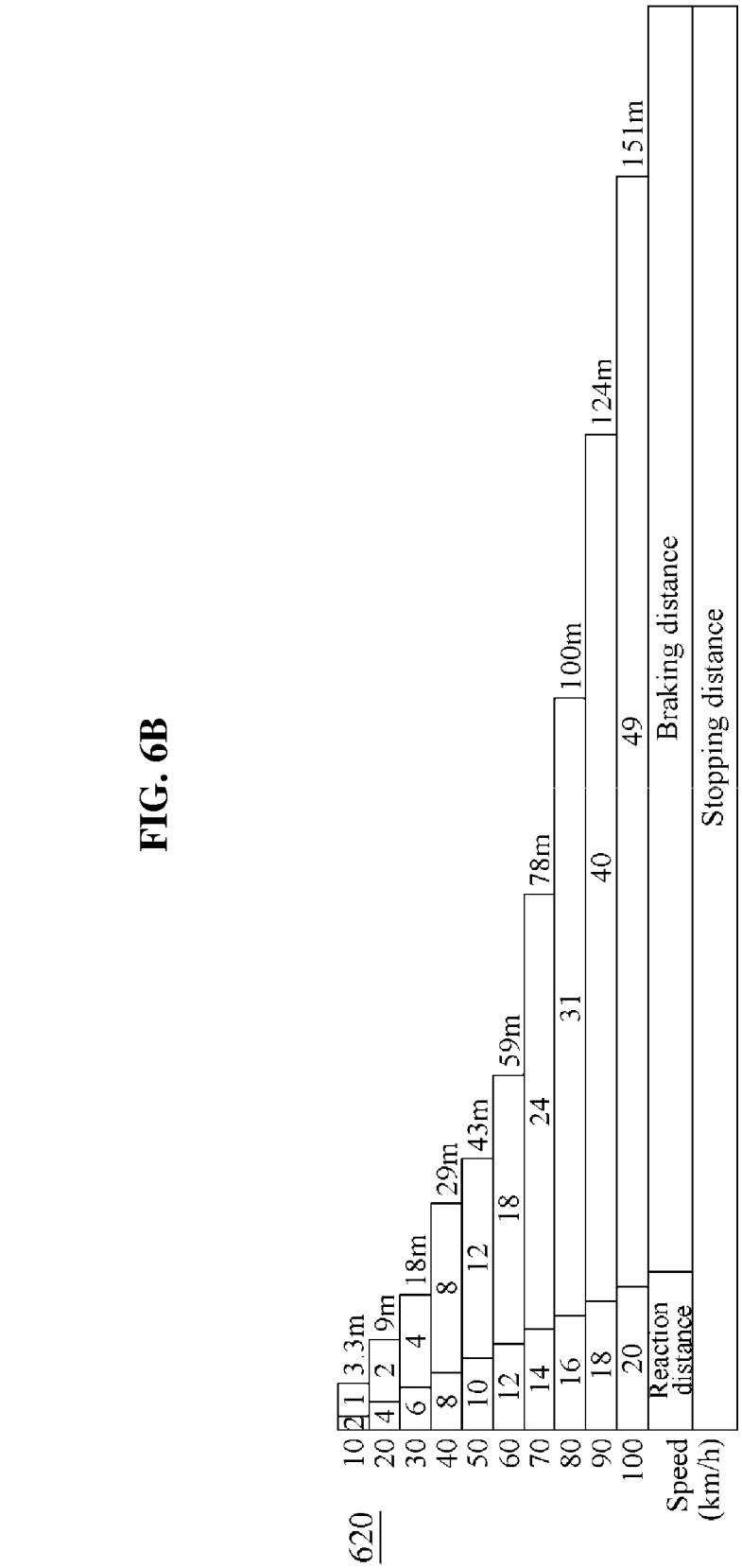

620
Speed (km/h)
10
20
30
40
50
60
70
80
90
100
Reaction distance
Braking distance
Stopping distance
2
1
3.3m
4
2
9m
6
4
18m
8
8
29m
10
12
43m
12
18
59m
14
24
78m
16
31
100m
18
40
124m
20
49
151m

FIG. 7

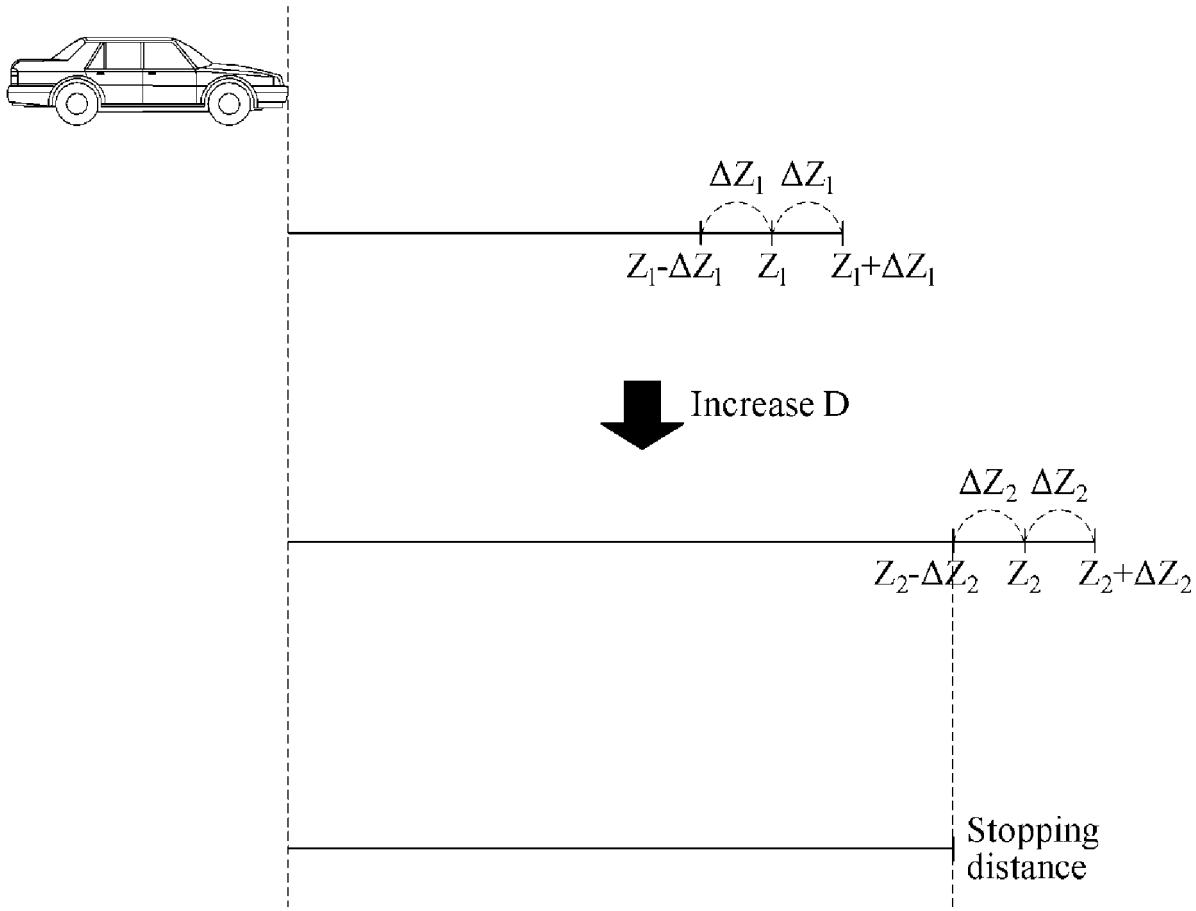

ΔZ1 ΔZ1
Z1-ΔZ1 Z1 Z1+ΔZ1
Increase D
ΔZ2 ΔZ2
Z2-ΔZ2 Z2 Z2+ΔZ2
Stopping distance

FIG. 8

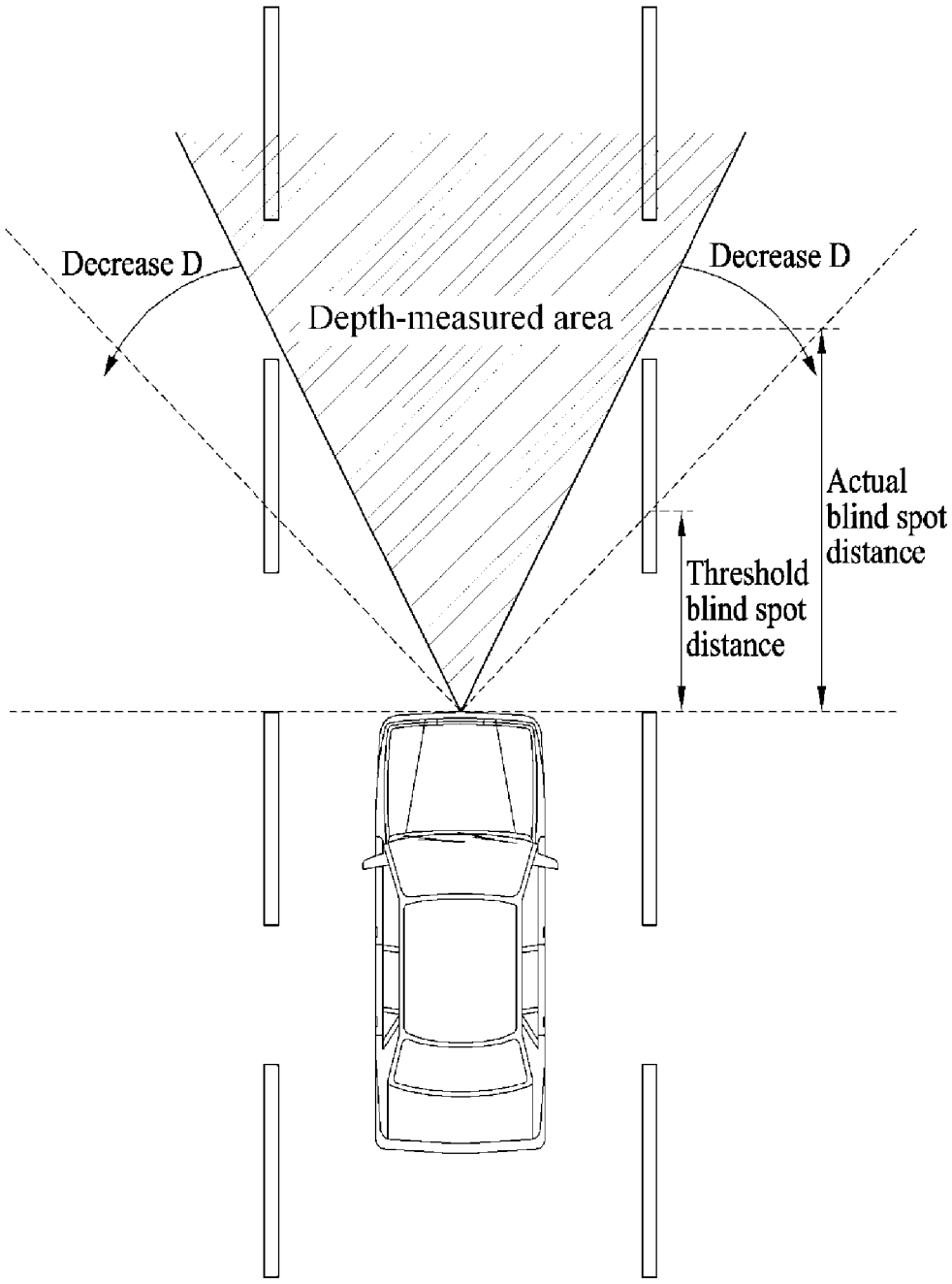

Decrease D
Depth-measured area
Decrease D
Actual blind spot distance
Threshold blind spot distance

FIG. 9

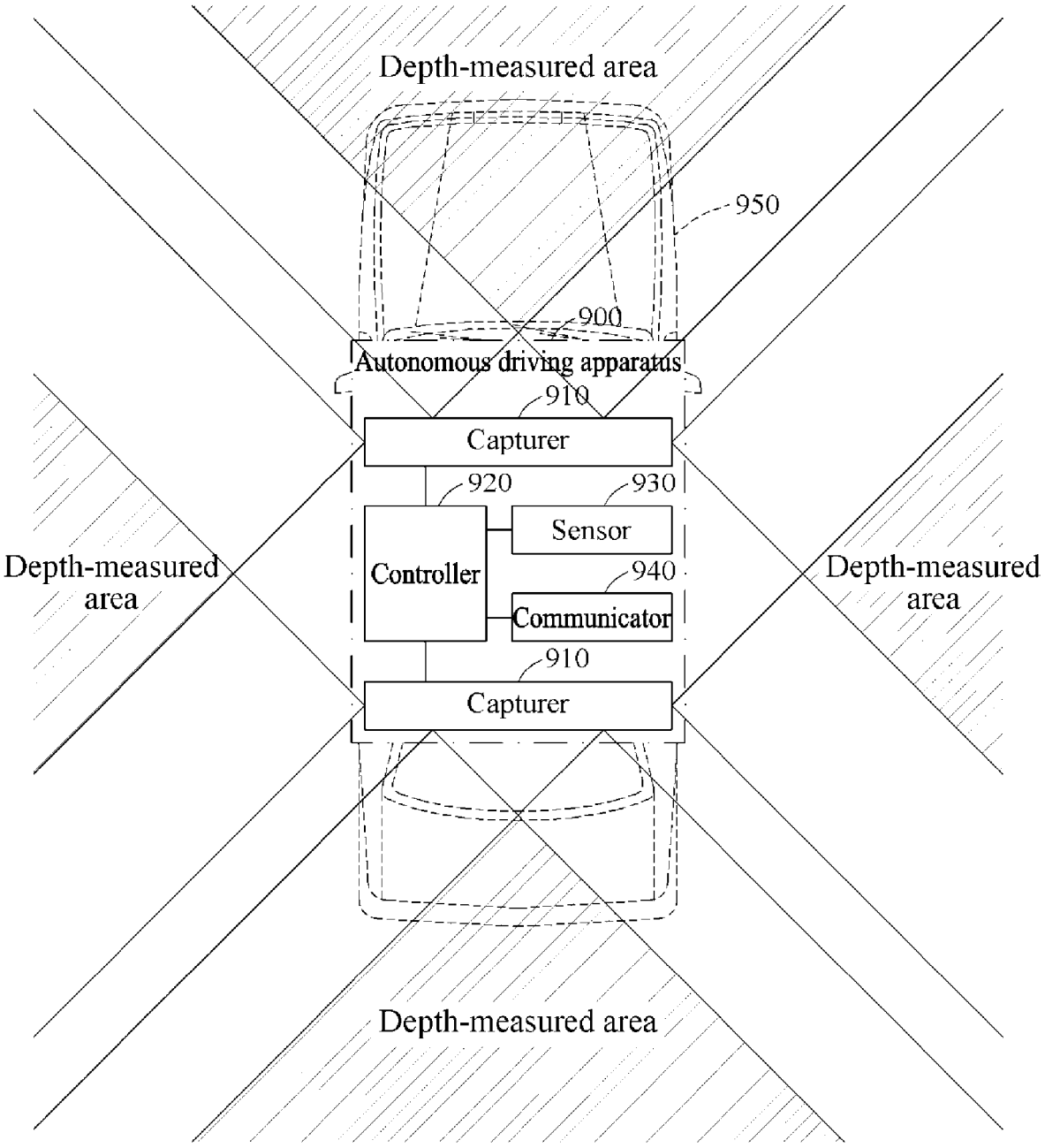
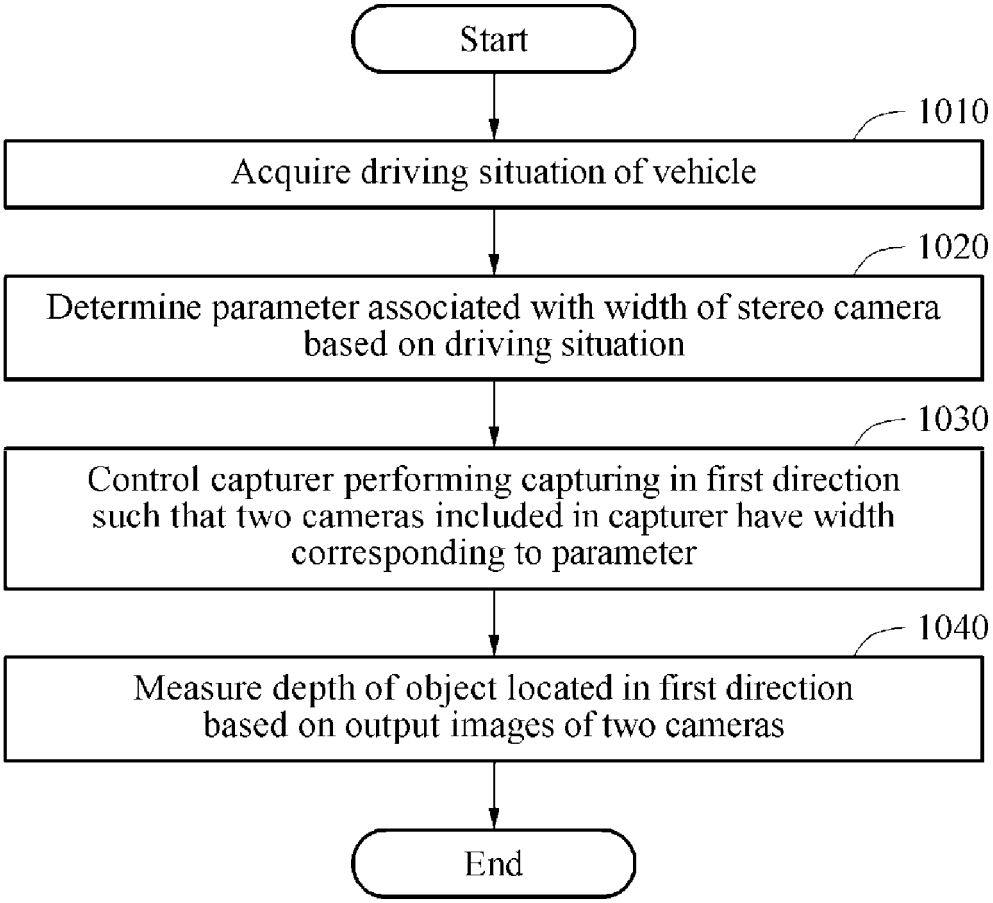

Depth-measured area
950
900
Autonomous driving apparatus
910
Capturer
920
930
Controller
Sensor
940
Communicator
910
Capturer
Depth-measured area
Depth-measured area
Depth-measured area

FIG. 10


Start
1010
Acquire driving situation of vehicle
1020
Determine parameter associated with width of stereo camera based on driving situation
1030
Control capturer performing capturing in first direction such that two cameras included in capturer have width corresponding to parameter
1040
Measure depth of object located in first direction based on output images of two cameras
End

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 2021143430 A1 **[0001]**
- US 20120113232 A1 **[0003]**
- US 20160205384 A1 **[0003]**
- US 9221396 B1 **[0003]**
- US 20120143430 A1 **[0003]**